Title
Impact of exergames on psychiatric symptoms in older adults with serious mental illness

Author
Heinbach, Michael Preston

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Impact of exergames on psychiatric symptoms in older adults with serious mental illness

by
Michael Preston Heinbach

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Approved:

DocuSigned by:
Dr. Heather Leutwyler
012039073579437...

Dr. Heather Leutwyler
Chair

DocuSigned by:
Astrid Block
DocuSigned by:
Janine Cataldo
FA15B61E76DB41D...

Astrid Block

Janine Cataldo

Committee Members

DEDICATION AND ACKNOWLEDGMENTS

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Impact of exergames on psychiatric symptoms in older adults with serious mental illness, Michael Preston Heinbach, Abstract

Objectives: Older adults with serious mental illness (SMI) are more likely to have high body mass index (BMI) and chronic conditions such as cardiovascular disease and diabetes. A sedentary lifestyle which may be attributed to pharmacologic side effects and the symptoms of mental illness, has been difficult to treat. Patients experiencing negative symptoms (e.g., apathy, anhedonia) may be more likely to exercise in a group setting with activities that are designed to stimulate the mind and encourage engagement. “Exergames” or exercise-based videogames, are an interactive and stimulating method to provide aerobic activities. Exercise has also been shown to reduce the symptoms of depression. The purpose of this study is to evaluate the impact of exergames on depressive and negative symptoms in older adults with SMI. **Materials and Methods:** A single-group pretest posttest study was conducted with 52 older adults diagnosed with SMI. Participants engaged in group exergame activities for 50-minute sessions three times a week for 10 weeks. The Patient Reported Outcome Measurement Information System or PROMIS, and the Scale for the Assessment of Negative Symptoms or SANS, were conducted at enrollment, 5 weeks, and 10 weeks. **Results:** Participants achieved statistically significant reductions in self-reported depressive symptoms (-0.83, LL -1.46, UL -0.12) and observed negative symptoms (-5.29, LL -7.64, UL -2.94) over a 10-week period. **Conclusions:** Our results suggest utilization of exergames as an adjunct treatment can be an effective, engaging, and cost-efficient method to reducing depressive and negative symptoms in older adults with SMI. Future studies should evaluate exergame effects with a larger sample.

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LIST OF ABBREVIATIONS

BC: BIAS CORRECTED

BMI: BODY MASS INDEX

CI: CONFIDENCE INTERVAL

DVD: DIGITAL VERSATILE DISC

EM: EXPECTATION-MAXIMIZATION

FIML: FULL INFORMATION MAXIMUM LIKELIHOOD

n: SAMPLE SIZE

NIH: NATIONAL INSTITUTE OF HEALTH

NIMH-MATRICS:

PI: PRINCIPAL INVESTIGATOR

PROMIS: PATIENT REPORTED OUTCOME MEASUREMENT INFORMATION SYSTEM

PTSD: POST TRAUMATIC STRESS DISORDER

RCT: RANDOMIZED CONTROL TRIAL

SANS: SCALE FOR THE ASSESSMENT OF NEGATIVE SYMPTOMS

SD: STANDARD DEVIATION

SMI: SERIOUS MENTAL ILLNESS

WA: WASHINGTON

Purpose statement: The purpose of this paper is to explore the impact of exergames on depressive symptoms in patients with serious mental illness.

Aims: In this paper, we aim to describe the effect of a 10-week videogame-based exercise program on depressive symptoms and negative symptoms in patients with SMI.

Introduction / Background:

Nearly a quarter of all patients with schizophrenia will soon be over the age of 55, and this number is expected to increase to 1.1 million people by 2025. Worldwide, the number of people age 60 or greater is projected to more than double by 2050.[1] Despite the fact that this population is living longer on average, their health and quality of life are not optimal. Schizophrenia is a major cause of disability-adjusted life years in people 60 and older.[2] Depression is now the leading cause of disability in the world [3] and community dwelling patients with schizophrenia over the age of 45 have much higher rates of depression compared to their same aged peers.[4] Older patients with schizophrenia incur some of the highest healthcare costs in our population exceeding patients with dementia and depression.[5]

Serious mental illness or SMI is characterized by the American Psychological Association as distinct conditions that require routine management, produce functional impairment, and interfere with quality of life.[6] Individuals that typically meet the criteria of SMI have illnesses that include schizophrenia, schizoaffective disorder, psychotic disorders, major depressive disorders, bipolar disorders, and borderline personality disorder.[7] For the purposes of this paper, serious mental illness will be defined as patients diagnosed with schizophrenia, schizoaffective disorder, anxiety disorder, PTSD, and/or major depression. Patients with serious mental illness are burdened with nearly double

the prevalence of obesity compared to the same demographic group without SMI in the United States.[8] The comorbidities in adults with serious mental illness may be due to psychiatric medication metabolic effects, as well as sociodemographic issues and lack of exercise.[9]

Patients with SMI on average die 25 years before their non-afflicted peers.[10] Forty percent of these premature deaths are due to suicide or other unnatural causes and 60% of these premature deaths are due to health complications such as cardiovascular or pulmonary disease.[10] Mental health symptoms and metabolic or cardiopulmonary disorders may all be improved with increased exercise.[11] A meta-analysis in 2017 found schizophrenia to have a substantial effect on potential life lost, suggesting that efforts to reduce this gap in mortality are needed[12] such as exciting and engaging exergames that can provide physical activity while being psychologically stimulating.

The American Heart Association endorses the potential in exergames as a new and innovative technology that can engage populations who are otherwise inactive.[13] The American College of Sports Medicine and American Heart Association recommend that all healthy adults aged 18 – 65 need moderate-intensity aerobic (endurance) physical activity for a minimum of 30 minutes on five days each week or vigorous-intensity aerobic physical activity for a minimum of 20 minutes on three days each week.[14] Monedero, Murphy and O'Gorman found that active video games are significantly more enjoyable than traditional exercise and provide moderate or vigorous physical activity to meet the requirements of the American College of Sports Medicine.[15] A recently published meta-review confirmed that exercise reduces depression in all age groups including older adults and could be used as adjunctive treatment for reducing negative symptoms of

schizophrenia. The meta-review suggests exercise can be an effective part of a treatment regimen for improving symptoms in a broad range of mental disorders.[16]

Exergames have shown to improve game participation attendance and in-session engagement enhancing aerobic fitness in patients with schizophrenia.[17] Exergames were found to provide a higher degree of entertainment and variety which minimized boredom of aerobic exercises. Exergame structure provides multiple high-intensity short training segments which has been shown to be more effective than low intensity prolonged aerobic activities.[18] Videogame based physical activity programs have been shown to provide a clinically meaningful increase in walking speed in adults with schizophrenia and in self-reported physical activity levels.[19] Exergames have been shown to be effective methods at increasing physical activity levels in youth with high BMI.[15]

Patients with schizophrenia experience negative symptoms including apathy, anhedonia, reduced social drive, loss of motivation, and lack of social interest. Social dysfunction is a hallmark of the disease.[20] In addition, community dwelling older adults over the age of 45 living with schizophrenia have much higher rates of depression then their peers without schizophrenia.[21] These symptoms tend to be resistant to pharmacological or group therapy treatments, but preliminary evidence suggest a response to modalities such as dance and movement therapy.[2] Motivation enhancement training have also shown promise as a useful modality to improve negative symptoms in pilot studies.[22] Social skills training has been shown in randomized controlled trials (RCTs) to improve psychosocial and community functioning, self-efficacy, negative symptoms and social skills in patients with SMI.[23]

Exergames enhance social well-being, reduced loneliness, increased positive attitudes towards others and social connections in older adults.[24] Exergames also improve overall positive psychological and behavioral outcomes while enhancing user motivation.[25] Exercise video games or exergames have been shown to provide positive social contact and improve motivation in patients with SMI.[26] While there is evidence to show exercise can reduce depressive symptoms, reduce rates of metabolic disease, and that group exergames can improve social interactions and motivation in patients with SMI, there is a lack of evidence in the literature exploring exergames and its effects on depressive symptoms in patients with SMI. Therefore, the purpose of this paper is to explore the impact of exergames on depressive symptoms in patients with serious mental illness. We hypothesized that statistically significant reductions in negative and depressive symptoms would be detected after participants with SMI engaged in a 10 week exergame program.

Methods

To be included in the study, participants had to be English speaking adults 45+ years old with a diagnosis of SMI that pass a capacity to consent test based on comprehension of the consent form. A convenience sample was recruited from a transitional residential facility for older adults with SMI or an outpatient assertive community treatment center. Subjects were excluded if they had known medical conditions or other physical problems that need special attention in an exercise program (i.e. prior myocardial infarction, uncontrolled hypertension, history of angioplasty, history of angina, use of nitroglycerin to treat angina).

Three times a week for 10 weeks, participants played an active video game, using the Kinect for Xbox 360 game system (Microsoft, Redmond, WA), for 50-minutes. The Kinect for XBox 360 system does not require participants to use a controller. Instead, participants use their body to directly control the game. The Kinect sensor utilizes full-body tracking that recognizes the participant's body and mirrors movements in the game. Some games, like Tai-Chi, provide the participants with feedback about how to correct their body movements to correctly match the coach on the screen. Each participant had the appropriate amount of space in order to have full range of motion. Approximately six feet of free space between the participant and the X-Box Kinect sensor is needed. The sessions took place in a room at a transitional residential facility or an outpatient clinic.

The games offer a variety of levels and each group started off at the beginner level. Participants were taught warning signs to be aware of while exercising (e.g., shortness of breath, dizziness). Participants were encouraged to discontinue the game if they noticed any exercise warning sign. The PI or her staff were present during the groups to assist with setting up the games and to monitor participants during the games. Each 10-week group started with bowling from the Kinect Sports DVD and then participants were given the option of 10 games to try for each additional session. All participants eventually played the same 10 games. These games included: Kinect Sports (bowling, baseball, golf, tennis, and skiing), Kinect Dance Central 2, Kinect Adventures (River Rush and 20,000 Leaks), and Kinect Your Shape Fitness Evolved (Tai-Chi and Body Focus Workouts). All of the games were chosen based on feedback from previous participants and research staff experiences playing the different games in groups of people with SMI. One day a week focused on games that promote coordination and balance, one day focused on

games that promote aerobic activity, and one day focused on games that promoted strength and flexibility. Participants engaged in the program in groups of up to 5. Participants took turns playing the games. Some games, such as skiing, allowed for multiplayers at one time. Participants started off the 10-week sessions with single player turns so that they could learn how to play the games. As the participants become more adept at the games, multiplayer games were encouraged so that participants could play for longer periods of time and have more frequent turns.

Measures

In addition to completing questionnaires and assessments about clinical and sociodemographic information, participants were assessed with the following instruments.

The National Institute of Health (NIH) funded the development of the Patient Reported Outcome Measurement Information System or PROMIS. The purpose of developing this measure was to form a validated measurement tool for patient reported outcomes to be utilized across studies and conditions allowing for the comparison of findings.[27] The World Health Organization's framework of health made up of physical, mental and social domains provided the basis for the tool's development.[27] The PROMIS-29 includes 29 questions using a Likert scale of 1-5: Never, Rarely, Sometimes, Often, and Always respectively. The tool includes questions about Physical Function, Anxiety, Depression, Fatigue, Social Roles/Activities, Pain Interference, and Pain Intensity in the past seven days. While only one section with 4 questions directly asks about depression, (asks about feeling worthless, helpless, depressed, and hopeless), other sections ask about common manifestations or contributory factors of depression ("worries overwhelmed," "feeling

fatigued," "trouble starting things because I am tired," "how run-down did you feel," "ability to do regular personal and household responsibilities," "sleep quality and difficulty falling asleep").[27] The Patient-Reported Outcomes Measurement Information System or PROMIS has been shown to be a reliable, precise and valid measure of multiple health related outcomes including depression.[28]

The SANS or Scale for the Assessment of Negative Symptoms developed by Andreasen[29] in 1989 is the most widely used rating scale for negative symptoms in patients with schizophrenia. According to the NIMH-MATRICS consensus statement on negative symptoms, the SANS is the preferred scale in this patient population.[30] The Scale for the Assessment of Negative Symptoms shows excellent interrater reliability when measuring negative symptoms in schizophrenia.[31] It has been shown to be a reliable [32] and valid [33] scale when assessing Negative symptoms in schizophrenia and the SANS can be used to record negative symptoms over time and response to treatments.[29]

Assessments were completed prior to starting the exergame program and after five and 10 weeks of the program. A trained interviewer conducted the SANS and participants self-reported information in the PROMIS measure.

Analysis

Multilevel linear regression models (also called random regression models, linear mixed models, and hierarchical linear models) were used to test change across time for all outcome measures.[34,35] An advantage of the multilevel regression approach over more traditional repeated measures analysis of variance (RMANOVA) that is often used for this analysis, is that multilevel regression models can be estimated when predictors are

continuous as well as categorical (as expected for RMANOVA). The effects of predictors at baseline (the first assessment), and the effects of predictors of the change trajectory can be estimated with multilevel regression models. In addition, multilevel regression can provide unbiased estimates of change or of the effect of predictors on change even if some assessments of the outcome are missing or participants drop out from the study. This is possible through the use of Full Information Maximum Likelihood (FIML) [36] with the Expectation-Maximization (EM) algorithm.[37]

This method provides unbiased parameter estimates as long as the missingness is ignorable. Even if participants only provide data at the initial assessment, their data contributes to the estimation of the intercept (e.g., mean at baseline) and intercept variance. Participants contribute information to the analysis for as many times as they provide data. The missing data that did occur is assumed to be missing at random (one type of "ignorable.")[38,39,40] This assumption is a reasonable assumption for the outcomes of interests, because it is unlikely that participants did not provide assessments of the measures because of the values that would have been reported had they been assessed. For example, it is unlikely that a client would have avoided being assessed for anxiety at an assessment, because she or he did not want to reveal her or his level of anxiety at that assessment.

Distributions of the PROMIS depression outcome measures were non-normal (e.g., ordinal with a 0-3 scale), and so the assumption of normal errors was not justified.[34,35] Therefore, and in order to allow interpretation of effects on the original scale for the PROMIS depression scores, estimation was carried out with a bootstrap in order to draw inferences about statistical significance. The bootstrap[41,42,43] may be carried out

in several ways: with inference based on a z-test using bootstrapped standard errors assuming normality, percentile-based confidence intervals, or nonparametric bias-corrected confidence intervals (BC CI). The present analyses employed the nonparametric bootstrap in order to obtain non-parametric bias-corrected bootstrapped confidence intervals using 5,000 repetitions. In using bootstrapped confidence intervals to draw conclusions about statistical significance for our quantitative outcome, a regression coefficient or other effect was considered to be significant if zero was not in the interval. For all analyses, estimation was carried out with Stata/SE Release 16,[44] using a two-sided alpha of 0.05.

Results:

A total of 52 participants were included in the analyses. The majority of participants were male and the average age for the overall sample was 59.2 (49 - 71; ±5.3). Twenty-seven participants were current smokers, 16 were past smokers, and 9 never smoked. The mean number of sessions attended was 17 out of 30 total (SD=9).

Table 1: Characteristics of Participants

Table 1. Characteristics of Participants, n=52	
Characteristic	% (n) or Mean (SD)
Age (years)	59.2 (49 - 71; ±5.3).
Male	61.5 (32)
Female	38.5 (20)
White	49 (26)
Black/African American	24.5 (13)
Latinx	1.9 (1)
Asian	11.3 (6)
Other	9.4 (5)
First Language English	88.7 (47)
Past Substance Use Disorder	16 (30)
Schizophrenia	43.4 (23)

Characteristic	% (n) or Mean (SD)
Schizoaffective	5.7 (3)
Major Depression	20.8 (11)
Anxiety	1.9 (1)
Bipolar Disorder	9.4 (5)
Psychosis (Not Otherwise Specified)	3.8 (2)
Post-Traumatic Stress Disorder	9.4 (4)
Age at Onset of First Psychiatric Symptoms (years)	30.2 (15.6) n=42
Age at First Psychiatric Hospitalization (years)	31.9 (16.6), n=42
Total Psychiatric Hospitalizations (count)	7.8 (9.72), n=42
Years of education	13.04 (2.76), n=50

Results of the multilevel linear regression are in table 2 and illustrated in figures 1 and 2. These changes in psychiatric symptoms were found to be significant with a 95% confidence interval. Neither confidence interval contained zero indicating a significant change occurred. Analyzing the PROMISE data, the predicted mean score from the linear analysis for the sample at enrollment was 10.15 points. For each additional 5 weeks of engaging in the physical activity program, self-reported depression scores decreased on average 0.83 points, or 1.66 points over the entire 10 week study period as illustrated in Figure 1, *PROMIS Depression Scores*. Analyzing the SANS data, the predicted mean score from the linear analysis for the sample at enrollment was 26.89. For each additional 5 weeks of engaging in the physical activity program, investigator assessed psychiatric symptom scores decreased on average 5.29 points, or 10.58 points over the entire 10 week study period as illustrated in Figure 2, *Negative Assessment of Symptoms*.

Table 2: Change in psychiatric symptoms over a 5 week physical activity program:

Statistical Model Data Source:	Estimate	95% CI	
		Lower Bound	Upper Bound
PROMISE			
Initial Score	10.15	9.37	10.83
Coefficient	-0.83	-1.46*	-0.12*
SANS			
Initial Score	26.89	23.32	30.46
Coefficient	-5.29	-7.64	-2.94

* Lower and upper limits for the nonparametric bootstrapped bias-corrected confidence interval (5,000 repetitions): If zero is in the interval, the coefficient is not significant (two-sided alpha = .05)

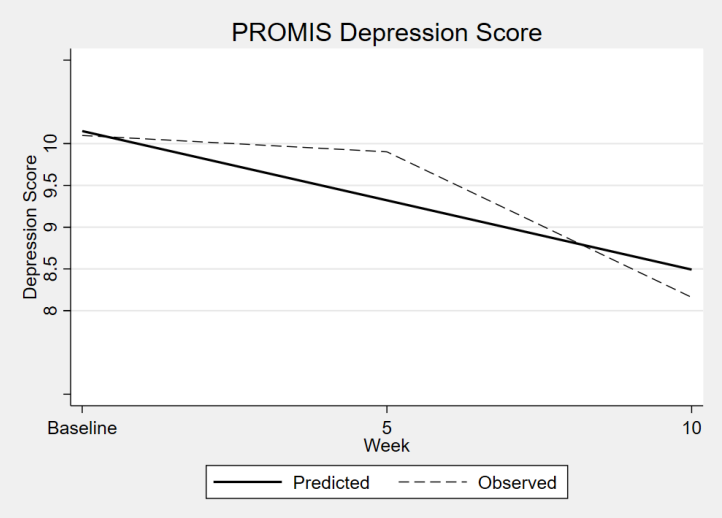

Figure 1: Patient-Reported Outcome Measures Information System: observed decline in mean scores and predicted decline based on the nonparametric bootstrap with 5,000 repetitions.

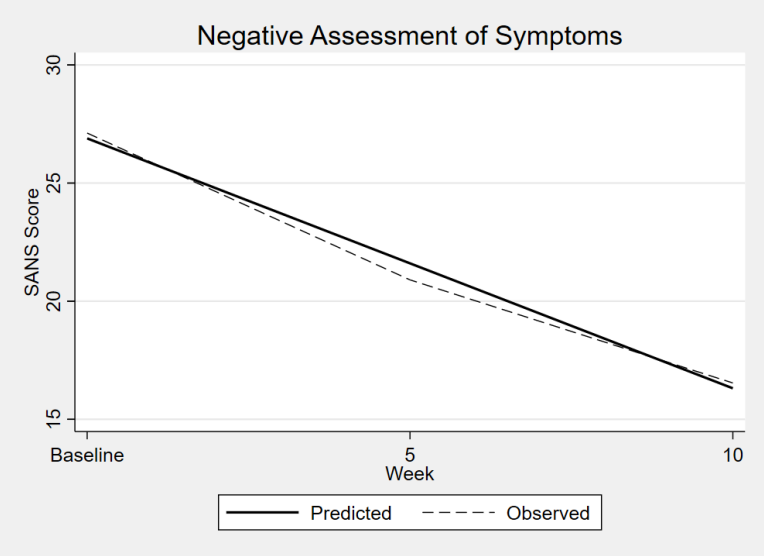

Figure 2: Scale for the Assessment of Negative Symptoms: observed decline in mean scores and predicted decline.

Discussion:

This study is the first to specifically evaluate the utilization of exergames and their effects on depressive and negative symptoms in older adults with SMI while in a transitional care or outpatient setting. We theorized that the process of play, social interactions, and physical engagement provided by exergames over a 10-week period would have a positive impact on older adult patients with SMI and their mental health. We utilized two reliable, validated and commonly implemented mental health assessment tools to show the impact of exergames on depressive and negative symptoms.

Our results showed a statistically significant effect in reducing self-reported depressive symptoms and observed negative symptoms in older adults with serious mental illness. These findings suggest group exergame activity programs offered on site at a mental health transitional care facility or outpatient clinic is an effective adjunct modality in reducing negative symptoms of depression in this older patient population with SMI.

An RCT in 2017 enrolled and retained over one hundred older adult participants with subsyndromal depression, for a six-week study comparing one-hour weekly Nintendo wii based exergame sessions to comparable traditional physical activity for the same time and frequency. Similar to our findings, the authors found a statistically significant decrease in depressive symptoms as measured with the Patient Health Questionnaire – 9. Interestingly, the group playing exergames showed a greater statistically significant decrease in depressive scores than the traditional exercise group.[45] The authors concluded exergames are more beneficial for reducing subsyndromal depression in older adults when compared to traditional exercise as a control. This study assessed a similar older adult patient population, with less acute depression, utilizing an analogous intervention and found results comparable to ours. Further research should be done to assess for additional improved health outcomes such as an effect on changes in societal involvement, self-efficacy, long-term reduction in depressive symptoms, improved mobility or a prolongation of functional mobility, and a reduction of overall healthcare expenditures compared to traditional exercise interventions.

Utilization of an exergame regimen stands out from more traditional modalities because it is relatively easy to incorporate into the daily routine of a treatment program with little cost burden on staff to facilitate.[4619] The initial cost of an appropriate gaming console can be purchased new for approximately $250 (Amazon at time of publishing).[47] This is comparable to single activity stationary exercise equipment such as bicycles or rowing machines[48] which are unable to change the form of exercise provided and therefore may be less engaging for users. Exergames require little dedicated storage space when not in use,[49] and can utilizing shared space from other activities.

Our exergame program is cost reducing when compared to a traditional physical activity program. A comparable ten-week traditional exercise program performed by a "Healthcare Support Worker" Bureau of Labor and Statistics Job #31-9099, at a national average hourly rate of $19.24/hr[50] x 1hr sessions (comparable to 50 minutes plus set-up and take-down of exergame equipment) x 3 sessions /week x a 10 week program, would cost $577.20 to implement. This is more than double the cost of an exergame console and would not be "re-usable" for future patients. The cost of these gaming consoles as well as their games are relatively inexpensive, and reusable compared to repeated in-person classes organized and run by healthcare staff or support workers. After the initial financial cost of the exergame equipment, the time commitment from current staff would be minimal for set up and take down. Our research team's experience facilitating exergames required minimal direction and supervision suggesting that sessions could easily be run as peer lead groups.

In 2015 Waldman-Levi, Bar-Haim, & Katz suggested play be incorporated into the concept of wellbeing for older adults. Their study suggested play may help increase feelings of positive self-concept and empowerment.[51] Improving these playful feelings may be why exercise reduced negative and depressive symptoms in our older adult population with SMI. Further research should be done to evaluate the effects of an exergame treatment modality compared to the current standard of care.

Limitations:

Our study was limited by the loss to follow up of patients not completing all three rounds of surveys. The average number of sessions attended was 17 out of 30 which limited data points. This missing data was accommodated by using the multilevel

regression method of analysis. Another possible limitation is participant bias. Study participants could have answered surveys in a way they believed the researcher would have wanted. Our study design however with five weeks between survey sampling, would have made recall of previous answers difficult. Furthermore, utilizing a combination of self-reported surveys (PROMIS) and an interviewer assessment for signs of negative symptoms (SANS) limited participant bias. Our study design lacked a control group which weakens the argument for a causative change from exergames use. Our results however are comparable to other researchers' findings using similar modalities with similar patient populations. A potential next step for future studies is to compare an intervention group to standard treatment in a RCT. Our study used only one highly trained researcher to perform the SANS interviews. This assured a high level of intrarater and interrater reliability further excluding any bias from inconsistencies among different interviewers.

Conclusion:

We concluded the use of exergames for older adults with SMI reduce depressive symptoms and therefore utilization of exergames as a modality in this patient population should be implemented clinically and safely to improve patient outcomes. The results of this study can be used to support the introduction and use of a creative and novel physical activity program for older adults with SMI that can be easily and cost efficiently incorporated into a daily routine for patients at a mental health facility. This study contributes to the growing body of literature indicating play and social connections, facilitated by exergames, lead to an improvement in patients' depressive symptoms among older adults with SMI.

References:

1. United Nations. World population prospects: The 2017 revision. *United Nations*. 2017.

2. Martin LAL, Koch SC, Hirjak D, Fuchs T. Overcoming disembodiment: The effect of movement therapy on negative symptoms in Schizophrenia—A multicenter randomized controlled trial. *Frontiers in psychology*. 2016;7(1):483. doi: 10.3389/fpsyg.2016.00483.

3. Friedrich MJ. Depression is the leading cause of disability around the world. *JAMA*. 2017;317(15):1517. doi: 10.1001/jama.2017.3826.

4. Meesters PD, Comijs HC, Sonnenberg CM, et al. Prevalence and correlates of depressive symptoms in a catchment-area based cohort of older community-living schizophrenia patients. *Schizophrenia Research*. 2014;157(1-3):285-291. doi: 10.1016/j.schres.2014.05.002.

5. Hendrie HC, Tu W, Tabbey R, Purnell CE, Ambuehl RJ, Callahan CM. Health outcomes and cost of care among older adults with schizophrenia: A 10-year study using medical records across the continuum of care. *American Journal of Geriatric Psychiatry*. 2014;22(5):427-436. doi: 10.1016/j.jagp.2012.10.025.

6. American Psychological Association. Proficiency in psychology: Assessment and treatment of serious mental illness. *American Psychological Association*. 2009:1-72.

7. Ruggeri M, Leese M, Thornicroft G, Bisoffi G, Tansella M. Definition and prevalence of severe and persistent mental illness. *The British Journal of Psychiatry*. 2000;177(2):149-155. doi: 10.1192/bjp.177.2.149.

8. Dickerson FB, Brown CH, Kreyenbuhl JA, et al. Obesity among individuals with serious mental illness. *Acta Psychiatrica Scandinavica*. 2006;113(4):306-313. doi: 10.1111/j.1600-0447.2005.00637.x.

9. Allison DB, Newcomer JW, Dunn AL, et al. Obesity among those with mental disorders: A national institute of mental health meeting report. *American journal of preventive medicine*. 2009;36(4):341-350. doi: 10.1016/j.amepre.2008.11.020.

10. Tiihonen J, Lönnqvist J, Wahlbeck K, et al. 11-year follow-up of mortality in patients with schizophrenia: A population-based cohort study. *Lancet, The*. 2009;374(9690):620-627. doi: 10.1016/S0140-6736(09)60742-X.

11. Scheewe TW, Backx FJG, Takken T, et al. Exercise therapy improves mental and physical health in schizophrenia: A randomised controlled trial. *Acta Psychiatr Scand*. 2013;127(6):464-473. doi: 10.1111/acps.12029.

12. Hjorthøj C, Stürup AE, McGrath JJ, Nordentoft M. Years of potential life lost and life expectancy in schizophrenia: A systematic review and meta-analysis. *The Lancet Psychiatry*. 2017;4(4):295-301. doi: 10.1016/S2215-0366(17)30078-0.

13. Lieberman DA, Chamberlin B, Medina Jr E, Franklin BA, Sanner BM, Vafiadis DK. The power of play: Innovations in getting active summit 2011: A science panel

proceedings report from the american heart association. *Circulation*. 2011;123(21):2507-2516. doi: 10.1161/CIR.0b013e318219661d.

14. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health - updated recommendation for adults from the american college of sports medicine and the american heart association. *Circulation*. 2007;116(9):1081-1093.

15. Javier Monedero, Enda E. Murphy, Donal J. O'Gorman. Energy expenditure and affect responses to different types of active video game and exercise. *PLOS ONE*. 2017;12(5):1-13. doi: 10.1371/journal.pone.0176213.

16. Ashdown-Franks G, Firth J, Carney R, et al. Exercise as medicine for mental and substance use disorders: A meta-review of the benefits for neuropsychiatric and cognitive outcomes. *Sports Med*. 2020;50(1):151-170. doi: 10.1007/s40279-019-01187-6.

17. Kimhy D, Khan S, Ayanrouh L, et al. Use of active-play video games to enhance aerobic fitness in schizophrenia: Feasibility, safety, and adherence. *Psychiatric Services*. 2016;67(2):240-243. doi: 10.1176/appi.ps.201400523.

18. Stanton R, Happell B. A systematic review of the aerobic exercise program variables for people with schizophrenia. *Current Sports Medicine Reports*. 2014;13(4):260-266. doi: 10.1249/JSR.0000000000000069.

19. Leutwyler H, Hubbard E, Cooper B, Dowling G. Impact of a pilot videogame-based physical activity program on walking speed in adults with schizophrenia. *Community Ment Health J*. 2018;54(6):735-739. doi: 10.1007/s10597-017-0208-6.

20. Meesters PD, Stek ML, Comijs HC, et al. Social functioning among older community-dwelling patients with schizophrenia: A review. *American Journal of Geriatric Psychiatry*. 2010;18(10):862-878. doi: 10.1097/JGP.0b013e3181e446ff.

21. Zisook S, M.D, Montross L, Ph.D, Kasckow J, M.D, et al. Subsyndromal depressive symptoms in middle-aged and older persons with schizophrenia. *American Journal of Geriatric Psychiatry*. 2007;15(12):1005-1014. doi: 10.1097/JGP.0b013e3180a725ec.

22. Velligan DI, Roberts D, Mintz J, et al. A randomized pilot study of MOtiVation and enhancement (MOVE) training for negative symptoms in schizophrenia. *Schizophrenia Research*. 2015;165(2):175-180. doi: 10.1016/j.schres.2015.04.008.

23. Mueser KT, Pratt SI, Bartels SJ, et al. Randomized trial of social rehabilitation and integrated health care for older people with severe mental illness. *Journal of Consulting and Clinical Psychology*. 2010;78(4):561-573. doi: 10.1037/a0019629.

24. Li JH, Erdt M, Chen LX, Cao YY, Lee SQ, Theng YL. The social effects of exergames on older adults: Systematic review and metric analysis. *JOURNAL OF MEDICAL INTERNET RESEARCH*. 2018;20(6):e10486. doi: 10.2196/10486.

25. Matallaoui A, Koivisto J, Hamari J, Zarnekow R. How effective is “Exergamification”? A systematic review on the effectiveness of gamification features in exergames. *Proceedings of the 50th Hawaii International Conference on System Sciences*. 2017.

26. Dobbins S, Hubbard E, Flentje A, Dawson-Rose C, Leutwyler H. Play provides social connection for older adults with serious mental illness: A grounded theory analysis of a 10-week exergame intervention. *Aging & mental health*. 2018:1-8. doi: 10.1080/13607863.2018.1544218.

27. Bevans M, Ross A, Cella D. Patient-reported outcomes measurement information system (PROMIS): Efficient, standardized tools to measure self-reported health and quality of life. *Nursing Outlook*. 2014;62(5):339-345. doi: 10.1016/j.outlook.2014.05.009.

28. Cella D, Riley W, Stone A, et al. The patient-reported outcomes measurement information system (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005–2008. *Journal of Clinical Epidemiology*. 2010;63(11):1179-1194. doi: 10.1016/j.jclinepi.2010.04.011.

29. Andreasen NC. The scale for the assessment of negative symptoms (SANS): Conceptual and theoretical foundations. *British Journal of Psychiatry*. 1989;155(S7):49-52. doi: 10.1192/S0007125000291496.

30. Kirkpatrick B, Fenton WS, Carpenter J, William T, Marder SR. The NIMH-MATRICS consensus statement on negative symptoms. *Schizophrenia bulletin*. 2006;32(2):214-219. doi: 10.1093/schbul/sbj053.

31. Andreasen NC. Negative symptoms in schizophrenia. definition and reliability. *Arch Gen Psychiatry*. 1982;39(7):784-8.

32. Mueser KT, Sayers SL, Schooler NR, Mance RM, Haas GL. A multisite investigation of the reliability of the scale for the assessment of negative symptoms. *American Journal of Psychiatry*. 1994;151(10):1453-1462. doi: 10.1176/ajp.151.10.1453.

33. Rabany L, Weiser M, Werbeloff N, Levkovitz Y. Assessment of negative symptoms and depression in schizophrenia: Revision of the SANS and how it relates to the PANSS and CDSS. *Schizophrenia Research*. 2010;126(1):226-230. doi: 10.1016/j.schres.2010.09.023.

34. Hox JJ. *Multilevel analysis: Techniques and applications .* 7th ed. New York, NY: Routledge Academic: Taylor & Francis Group; 2010:1-500.

35. Singer JD, Willett JB. *Applied longitudinal data analysis: Modeling change and event occurrence.* New York: Oxford University Press; 2003:1154-1155.

36. Schafer JL, Graham JW. Missing data: Our view of the state of the art. *Psychol Methods*. 2002;7(2):147-177.

37. Muthen B, Shedden K. Finite mixture modeling with mixture outcomes using the EM algorithm. *Biometrics*. 1999;55(2):463-469.

38. Enders CK. A primer on the use of modern missing-data methods in psychosomatic medicine research. *Psychosom Med*. 2006;68(3):427-436.

39. Enders CK. *Applied missing data analysis.* US: Guilford Publications Inc. M.U.A; 2010.

40. Schafer JL. *Analysis of incomplete multivariate data.* Vol 72. New York; London: Chapman & Hall; 1997.

41. Wehrens R, Putter H, Buydens LMC. The bootstrap: A tutorial. *Chemometrics Intellig Lab Syst*. 2000;54(1):35-52.

42. Wood M. Bootstrapped confidence intervals as an approach to statistical inference. *Organ Res Methods*. 2005;8(4):454-470.

43. Zhu W. Making bootstrap statistical inferences: A tutorial. *Res Q Exerc Sport*. 1997;68(1):44-55.

44. StataCorp. *Stata statistical software. Release 16;* College Station, TX 2019.

45. Li J, Theng Y, Foo S, Xu X. Exergames vs. traditional exercise: Investigating the influencing mechanism of platform effect on subthreshold depression among older adults. *Aging & Mental Health*. 2018;22(12):1634-1641. doi: 10.1080/13607863.2017.1385722.

46. Groessl EJ, Kaplan RM, Blair SN, et al. A cost analysis of a physical activity intervention for older adults. *Journal of physical activity & health*. 2009;6(6):767-774.

47. Amazon.com. Xbox one S 1TB all-digital edition console. https://www.amazon.com/Xbox-All-Digital-Console-Disc-Free-Gaming/dp/B07XQXZXJC/ref=sr_1_1?dchild=1&keywords=xbox&qid=1588284422&sr=8-1. Updated 2020. Accessed April 30th, 2020.

48. Yang S, Smith B, Grahm G. Healthy video gaming: Oxymoron or possibility? *Innovate: Journal of Online Education*. 2008;4(4).

49. Staiano AE, Calvert SL. Exergames for physical education courses: Physical, social, and cognitive benefits. *Child Development Perspectives*. 2011;5(2):93-98. doi: 10.1111/j.1750-8606.2011.00162.x.

50. US Department of Labor. Bureau of Labor Statistics. May 2019 national occupational employment and wage estimates united states. https://www.bls.gov/oes/current/oes_nat.htm#29-0000. Updated 2020. Accessed March, 2020.

51. Waldman-Levi A, Erez AB, Katz N. Healthy aging is reflected in well-being, participation, playfulness, and cognitive-emotional functioning. *Healthy Aging Research*. 2015;4(1):1. doi: 10.12715/har.2015.4.8.

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